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ANALYSIS

Structural benefit transfer: An example using VSL estimates

V. Kerry Smith [a,*], Subhrendu K. Pattanayak [b], George L. Van Houtven [b,1]

[a] North Carolina State University, Center for Environ. and Resource Economic Policy, Department of Agric. and Resource Economics, Economics Policy, BOX 8109, United States
[b] RTI International, PO Box 12194, Research Triangle Park, NC, United States

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ABSTRACT

This paper describes and illustrates a method for benefits transfer referred to as preference calibration or structural benefits transfer. This approach requires selection of a preference model, capable of describing individual choices over a set of market and associated non-market goods to maximize utility when facing budget constraints. Once the structure is selected, the next step involves defining the analytical expressions for the tradeoffs being represented by the set of available benefit measures. These algebraic relationships are used with the benefit estimates from the literature to calibrate the parameters of the model. The calibrated model then offers the basis for defining the "new" tradeoffs required for the policy analysis, i.e., for 'transferring benefits'. A new application is used to illustrate the structural benefits transfer logic. It involves the benefits for mortality risk reductions, measured with labor market compensation a worker would accept to be willing to work with added risk. The measure is usually labeled the value of a statistical life (VSL). Our application indicates that we should not have expected differences in these measures for the economic value of risk reductions with age. The calibrated estimates were not greatly different for combinations of risk levels, labor supply choices, wages, and non-wage income for older adults. Thus, simple adjustments relying on value per discounted life year remaining seem questionable.

1. Introduction

It has been twenty-five years since the Presidential mandate to perform benefit-cost analyses for major regulations was first issued as Executive Order 12291 in February 1981. This order offered economists a place at the policy table — allowing them to add to the information available for judging the merits of "major" new rules and revisions to those already on the books. Benefit-cost methods are intended to summarize the tradeoffs people would make in giving up money, time, or other goods to get more of something else. In most situations where benefit-cost analyses are applied for environmental policy evaluations, the "something" that the policy provides is not available in private markets. As a result, analysts do not have a ready source for measuring the tradeoffs people make (at the margin) to obtain more of the goods or services involved. With most private goods, these marginal trade-offs can be measured using the commodity prices that are

* Corresponding author.
E-mail address: Kerry_Smith@ncsu.edu (V.K. Smith).

[1] University Distinguished Professor, North Carolina State University and Resources for the Future University Fellow; Fellow, RTI International and Research Associate Professor, North Carolina State University; and Program Director, Environmental and Natural Resource Economics, RTI International respectively. Partial support for this research was provided by the U.S. Environmental Protection Agency under a Star Grant no. RD 83-092301. Thanks are due two anonymous referees for helpful comments on an earlier draft of this paper and to Kenny Pickle for helping to prepare several drafts of this manuscript.

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determined in markets. In other situations, analysts must rely on revealed or stated preference methods to estimate the incremental benefits.

Generally, time constraints do not permit the new research required to estimate the benefits for each new or altered rule. Instead, benefit measures are developed from published research that has benefit measures for related situations. Policy analysts hope there is a close correspondence between one or more of the studies in the literature and policy needs. Unfortunately in many situations the correspondence is not direct.

The practices developed to adapt existing results or models measuring economic tradeoffs are usually labeled as *benefit transfers*. Four approaches have been used: unit value transfers, function transfers, meta model transfers, and structural model transfers. This paper describes and illustrates this last approach.

We proposed this method a few years ago and labeled it *preference calibration* (see Smith et al., 2002). The term structural transfer is probably a more descriptive general term. The structural approach requires selection of a preference specification, capable of describing an individual's choices over a set of market and associated non-market goods. These decisions are assumed to result from utility maximization subject to budget constraints. Once the structure is selected, the next step involves defining the analytical expressions for the tradeoffs being represented by the set of available benefit measures. These algebraic relationships are then used with the benefit estimates from the literature to calibrate the parameters of the model. The calibrated model offers the basis for defining the "new" tradeoffs required for the policy analysis, i.e., for developing "transferable" benefit measures.

This paper selects a new application to illustrate the structural benefits transfer logic and to show how it can be extended to differentiate between individuals with different observable characteristics (i.e., age and baseline risks). Our example involves the benefits for mortality risk reductions. These benefits are often measured with a concept known as the value of a statistical life (VSL). Section 2 provides a brief overview of the current practices used in benefits transfer. Section 3 outlines the logic of the structural method and adapts it to an expected utility framework. As part of this outline we discuss the potential to use labor supply estimates to inform risk valuation. Calibration of preference parameters is demonstrated using results from a hedonic wage-risk and a contingent valuation study. Section 4 considers the difficulties posed by allowing for different baseline risks across individuals who might also experience job related risks. To motivate this discussion we suggest one might assume baseline risk was a function of an individual's age. This section discusses how alternative models for including the effects of age can be integrated into the calibration logic. Section 5 discusses the philosophy underlying calibration and the interpretation of the models used for preference calibration as first steps in developing structural models. The last section comments on the advantages and disadvantages of the logic underlying the structural approach to benefits transfer.

2. Background

Environmental policy is generally motivated by specific goals (e.g. to protect human health or to provide swimmable waters in all rivers and lakes, etc.). Thus, it is natural to expect that the design and justification for public actions will have measurable outcomes associated with each of these goals. Most benefit analyses for policy use this goal orientation. As a result, they describe the effects of a policy by specifying an itemized list of changes in well-defined outcomes such as avoided cases of specific illnesses (for health effects due to reduced air pollution) or increased trips to a lake with improved water quality. Bromley (2005) refers to the process of defining these tangible effects as the "commoditization" of the services provided by environmental resources. Each unit is then valued using estimates derived from existing literature. These economic values are generally developed as unit benefit measures that are akin to "prices." These "prices" are recognized as approximations for more consistent benefit measures such as the marginal willingness to pay. The implicit "consumer spending" associated with the transferred benefit measure for improved services (i.e. the increased quantity of services times the relevant unit benefit measure) logic has emerged as a practical compromise to offer a transparent description of the computations.

As we noted in the Introduction, the most popular transfer methods fall into three groups. Each yields one or more unit value measures for the pre-defined effects that change due to the policy under evaluation. The first is a unit value transfer. It assumes the benefit measure is a constant. A value for the unit benefit can be derived from one study's estimate, as a mean of multiple estimates, or it can be administratively specified (see Rosenberger and Loomis, 2003 for more details).

The second approach labeled a function transfer usually relies on a function that has been estimated in the literature and is intended to describe behavioral choices. It could be a demand function for trips to a recreation site or an expression for the willingness to pay based on a stated preference study. In the former case, the demand function would be used to estimate a consumer surplus measure for a change that is intended to mimic the policy being evaluated. In the latter case (stated preference studies), the adaptation generally depends on the specification of the function reported in the original research (i.e. a random utility model or a variation function, see Cameron, 1988; McConnell, 1990 for discussion) and the available measures characterizing the pre-existing application area and the location that the proposed policy is intended to change.

The third approach based on meta functions uses statistical summaries of willingness to pay estimates or of these measures normalized by the amount of the change in the resource. Typically, meta-regression methods are used to relate the available benefit estimates to variables describing attributes of the resources (or environmental effects) studied, population characteristics from the past studies, and methodological attributes of the sources studies. These functions allow the dependent variable in each model, which is usually a measure of unit benefits, to be "adjusted" for what might be argued to be best practice methods as well as the circumstances of the policy applications (see Johnston et al., 2003).

There is an important contrast between the third approach and the use of a function transfer. For the most part, function transfers rely on models that are based on economic behavior. In contrast, meta models are statistical response surfaces — summaries of the empirical literature derived by treating the estimates as data — that do not necessarily correspond to a simple, unified conceptual model of economic behavior.[2] As a result, in several cases these meta-summaries combine, in an ad-hoc manner, estimates that are derived based on different benefit concepts, such as Marshallian and Hicksian measures for consumer surplus (see Smith and Pattanayak, 2002 for issues related to pooling these two types of data).

The fourth approach— structural benefits transfer— is, of course, not free of limitations. It requires the selection of a specific preference function so each benefit concept can be linked to the variables and parameters in that function. In this respect it parallels what would be done in the analysis of the primary data for a benefit analysis. We believe its greatest advantage is that it forces analysts to focus on both the benefit concept and the other determinants of the benefit measures to assure that they are consistently represented across studies. For example, the benefit measures, income, relative prices, etc. must all be in the same dollar units. To the extent assumptions about demographic characteristics influence the benefit measure, then some assumption about how to treat a study's summary statistics and the "typical" values for the demographic variables must be made.[3] Sometimes studies must be supplemented with information about the features of the area for each study that may not be reported in published accounts. Such data must be collected separately and augment the records extracted from the primary studies.

This process raises an implicit question. The logic of a structural transfer requires the analyst to judge whether the evidence in the literature is sufficient to identify all the parameters required by the preference function selected for a benefit transfer. At a conceptual level, this process draws attention to what would be required from a more complete model. It can induce policy analysts to question whether the available studies provide sufficient information for a transfer. It can also encourage the search for other non-valuation study sources of information.

The first three strategies dominate the literature. To our knowledge, aside from our published and unpublished papers, there is only one other application conducted as part of EPA's assessment of the benefits from visibility improvements associated with the clean air act (see U.S. Environmental Protection Agency, 1999).

3. Preference calibration with VSL measures

Conventional practice estimates the economic value of reductions in mortality risk based on the compensation workers are willing to accept to assume increased risks of death on the job. These estimates, labeled the VSL, are usually interpreted as the sum of the incremental values a set of workers would pay to reduce a common risk they face (e.g. accidental death from job hazards) so that the expected deaths declined by one individual.[4] They are an example of the effects/unit value logic we discussed earlier. The effect in this case is the reduction in mortality risk, measured as an expected number of deaths avoided by a group of people who experience reduced ambient air pollution. The unit value is the *ex ante* marginal rate of substitution, that is converted to a VSL because risk is expressed as a reduction in the expected number of deaths due to reduced exposures to the pollutant. The VSL is treated as a constant. In practice, a diverse set of behaviors has been used to attempt to estimate this *ex ante* MRS. The policy analyses using them have relied on informal reviews (Unsworth et al., 1992; Viscusi, 1993) or statistical meta analyses (Kochi et al., 2005; Mrozek and Taylor, 2002) to reconcile the results.

Models describing the wage/risk tradeoff focus on a decision process that envisions each individual selecting among an array of jobs. These alternatives would have different predefined characteristics including the working conditions, the risk of fatal accidents, and the compensation. With a continuous array of alternatives, at varying risks, and each individual's decision motivated by attempts to maximize expected utility (as given in Eq. (1)), the resulting tradeoff between risk and compensation can be described in Eq. (2). EU designates the expected utility.

$$\mathrm{EU} = (1-p)U^{\mathrm{A}}(\mathrm{W}) + pU^{\mathrm{D}}(\mathrm{W}) \tag{1}$$

where

p = probability of a fatal accident on the job
W = wage rate
$U^{\mathrm{A}}(\cdot), U^{\mathrm{D}}(\cdot)$ = state dependent utility functions conditioned by the outcome alive (A) and dead (D)

$$\mathrm{MRS}_{\mathrm{W}p} = \frac{\mathrm{dW}}{\mathrm{d}p} = \frac{U^{\mathrm{A}} - U^{\mathrm{D}}}{(1-p)U^{\mathrm{A}}_{\mathrm{W}} + pU^{\mathrm{D}}_{\mathrm{W}}} \tag{2}$$

where

$$U^j_{\mathrm{W}} = \frac{\partial U^j}{\partial \mathrm{W}}$$

In this framework job choice is assumed to reduce to a selection from alternative lotteries. At this general level there are few clues to use in selecting a functional relationship for $U^{\mathrm{A}}(\cdot)$ and $U^{\mathrm{D}}(\cdot)$.

Ordinarily in describing a work/leisure decision it would seem natural to look to specifications that arise in modeling labor supply. However, we were unable to find many applications where this connection was used to motivate VSL estimates. The only explanation we could locate is in an early discussion of the model by Viscusi (1979). He describes labor/leisure choices as part of a general treatment of time allocation and concludes that relaxing the assumption that individuals generally have a fixed number of hours worked in each job did not alter the implied tradeoff between wages and risk. Since one of the primary uses of the wage

[2] Of course, it is possible in principle to convert all the available estimates from different studies into a consistent measure for benefits. This strategy was adopted by Smith and Kaoru (1990) as well as several other authors. However, it has not been the uniform standard.

[3] This logic is similar to a discussion in the early literature on modeling demand about how to interpret the "representative individual" when aggregate data were used to estimate demand models. See Deaton and Muelbauer (1980) pp. 149–158 for discussion of these issues.

[4] See Hammitt (2000) and Freeman (1993) for discussion.

hedonic model has been compensation for undesirable features of a job, further attention to these other issues has been limited.[5]

Nonetheless, models for labor supply decisions and job choice are not incompatible alternatives. One could envision a choice setting where workers select among jobs, then conditional on that choice, evaluate the number of hours to be supplied. This perspective has some advantages because it offers another set of information (e.g. labor supply information) for calibrating preferences. To evaluate its potential, we selected a preference function relying on this basic logic. Following the framework outlined in Burtless and Hausman (1978) we specify a labor supply function and then derive the indirect utility function that would be consistent with it.[6]

Eq. (3) uses a semi-log specification for the labor supply. The corresponding indirect utility function is given in Eq. (4).

$$\ln(H) = \alpha + \beta W + \mu m \tag{3}$$

$$U^{A} = \frac{-\exp(-\mu m)}{\mu} + \frac{\exp(\alpha + \beta W)}{\beta} \tag{4}$$

where

m = non-wage income
W = wage rate
H = hours worked [7]

Therefore, a key advantage of this specification for U^A is that it guarantees a simple, observable, labor supply function.

To complete our description of expected utility and to link the resulting model to the VSL concept, we need to define the utility function that will be used for the state "death". For this part of the model, it is important to recognize that our description adopts an *ex ante* perspective. Thus, a utility function for the state "death" should be interpreted as an evaluation of that state by each individual at the time the job alternatives and results of working (both compensation and survival) are "potential" outcomes. From this orientation, $U^D(\cdot)$ is intended to reflect bequest motives. The function would typically not include the wage rate, but could be related to available non-wage income. It need not share the same functional form or parameters as what is implied by the state alive. Indeed, there are good reasons for assuming the marginal utility of income is different in the two states (see Cook and Graham, 1977 for a discussion of the properties of state dependent preference functions).

While this is certainly an important area for further research — we decided to keep this example simple. As a result, $U^D(\cdot)$ is assumed to correspond to the first term in the right side of Eq. (4) (dropping the contribution arising from labor/leisure choices). In this case the expected utility function is simplified directly as in Eq. (5). Eq. (6) provides the expression for the *ex ante* MRS.

$$EU = (1-p)\left[\frac{-\exp(-\mu m)}{\mu} + \frac{\exp(\alpha + \beta W)}{\beta}\right] + p\left[\frac{-\exp(-\mu m)}{\mu}\right] \tag{5}$$

$$-\frac{EU_p}{EU_W} = \frac{dW}{dp} = \frac{1}{(1-p)\beta} = \frac{W}{(1-p)\eta} \tag{6}$$

where

η = labor supply elasticity

$$EU_j = \frac{\partial EU}{\partial j}, \text{for } j = p, W$$

Eqs. (3) and (6) illustrate the types of connections between individual choice and a structural model that are used in preference calibration.[8] The first implies the parameters of labor supply should be related to VSL estimates. Eq. (6) describes the specific nature of the connection. One direct implication of this relationship is a connection between estimates of the labor supply elasticity together with an estimate of the wage and the job risk (p) and an implied VSL. Smith et al. (2003) use a few estimates from the literature to illustrate this logic. They find that the range of VSL estimates implied by the labor supply elasticities (together with mean values for the wage rate and job risks) is consistent with what has been found for direct estimates using hedonic models (see Viscusi, 1993; Mrozek and Taylor, 2002).

While this result is broadly supportive of the calibration logic, our purpose is actually to reverse the logic underlying Smith et al. (2003). That is, we propose to use estimates of the VSL, together with labor supply information and other estimates of how people evaluate risk/money tradeoffs, to recover "estimates" of the preference parameters. In our example, there are three parameters (α, β, μ) and the analysis to this point has considered two choices:

- job selection, which is implicit in the hedonic wage-risk equilibrium (Eq. (6)), and
- hours worked, which is captured in the labor supply function (Eq. (3)). A third source is needed to have enough information to calibrate this third parameter.

To address this issue we use one of the contingent valuation studies of risk/money tradeoffs. We rely on the Gegax et al., 1991 study because the risks are described as related to workplace activities. They report willingness to pay (and willingness to accept) estimates for non-marginal changes in risk. To use their results for calibration we need to define this *ex ante* WTP using our preference function. It is an option price — the non-wage income an individual would be willing to give up to receive the

[5] In an appendix he does suggest that models allowing a marginal time allocation lead to greater attention to the other sources of risk that each individual faces.

[6] Burtless and Hausman (1978) actually used a double log specification. A number of alternatives are possible. Our intention here is to illustrate the general logic so we selected a form that simplifies the algebra. Calibration generally requires a numerical solution of a set of nonlinear equations. Thus, more complex specifications can certainly be considered as long as the parameters to be recovered can be identified.

[7] The units used to measure hours correspond to what is relevant for the choice model. To link to VSL estimates, annual hours would be relevant.

[8] These are the types of models used in joint estimation, such as the scheme Cameron (1992) initially proposed.

lower risk described in their contingent valuation question.[9] Eq. (7) defines this relationship, with p_0 the initial job risk and p_1 the proposed lower risk that an individual is hypothesized to value at the option price, labeled here as $\tilde{WTP}$.

$$(1-p_0)\left[\frac{\exp(\alpha+\beta W)}{\beta}-\frac{\exp(-\mu m)}{\mu}\right]+p_0\left[\frac{-\exp(-\mu m)}{\mu}\right] = (1-p_1)\left[\frac{\exp(\alpha+\beta W)}{\beta}-\frac{\exp\left(-\mu\left(m-\tilde{WTP}\right)\right)}{\mu}\right] + p_1\left[\frac{-\exp\left(-\mu\left(m-\tilde{WTP}\right)\right)}{\mu}\right] \quad (7)$$

Rearranging terms we can define the option price for an incremental change in risk of death in Eq. (8).

$$\tilde{WTP}=\frac{1}{\mu}\ln\left[1+\frac{\mu}{\beta}\exp(\alpha+\beta W+\mu m)(p_0-p_1)\right] \quad (8)$$

Eqs. (3), (6), and (8) define the observed "choice relationships." Two features are important to their role in preference calibration. First, each expression is linked to the same basic function describing individual behavior. The logic does not use a $\tilde{WTP}$ estimate per unit of risk (i.e.$\tilde{WTP}/(p_0-p_1)$). Instead, it defines $\tilde{WTP}$ for a specific expected utility function and a specific risk change. It also assembles information necessary to calibrate the unknown parameters implied by that function. Second, and equally important, the logic recognizes that not all the information required for calibration may be found in a single study. Indeed, it may be necessary to supplement what is reported in available studies with other summary data. A first step in the process of using these relationships requires the interpretation of each to be made compatible with the other equations and with the available empirical information. The components of each relationship need to be constructed and measured so that they are individually consistent. The W and m relevant to a labor supply response from one study may be different from what is used in the contingent valuation study providing the $\tilde{WTP}$ estimate.

To illustrate the preference calibration logic directly, we select values for the "observables," variables in the three equations, substitute them into Eqs. (3), (6), and (8) and then solve for the unknown parameters. For example, using data from two related studies (Gegax et al., 1991; Gerking et al., 1988), and the ratios of non-wage to wage income from the National Income and Product Accounts, we can illustrate the calibration process for α, β, and μ.

The data used for this calibration include: (a) H=43.94 hours, (b) W=\$10.16, (c) m=\$1468, (d) VSL=\$1,580,544, (e) p=0.00086, (f) WTP=\$655, (g), p_0=0.00066, and (h) p_1=0.00041. All but m are taken from Gegax et al. (1991) and Gerking et al. (1988), or supplemented from the original survey, and are in 1983 dollars.[10] The three choice based relationships to be solved are given in Eqs. (9a)–(9c).

$$\ln(43.94)=\alpha+10.16\beta+1468\mu \quad \text{(labor supply)} \quad (9a)$$

$$1,580,544=(43.94\cdot 47.64)/(1-0.00086)\beta \quad \text{(VSL)} \quad (9b)$$

$$\exp(665\mu)=1+(\mu/\beta)^{*}43.94^{*}(0.00066-0.00041) \quad \text{(option price)} \quad (9c)$$

The resulting calibrated parameters are: α=180.91, β=0.00133, μ=−0.12067. For comparison with Burtless and Hausman we must convert β and μ into elasticities at the points used for calibration $\eta=\beta\cdot W$=0.0135 and the non-wage income elasticity of labor supply, ϕ, where $\phi=\mu\cdot m$=−177.14. Both are substantially larger in absolute magnitude than their findings (η_{BH}=0.00003 and ϕ_{BH}=−0.0477). However, these results rely on the subjective risk assessments and the VSL estimates implied by these assessments.

If instead we matched by industrial sector the average value for the risk of fatal accidents from the Bureau of Labor Statistics (BLS) data (the sample mean is p=0.0834) and the corresponding VSL estimates for the same sub-sample (i.e. VSL=11,837,610 in 1983 dollars) and recalibrate, the parameters would be α=29.56, β=0.000193, μ=−0.01756. The resulting elasticities η^*=0.00196 and ϕ^*=−25.78 are substantially smaller, and in the case of the η, this new result is closer to labor supply elasticities reported in Smith et al. (2003).

Some other details in the steps and assumptions made to derive relationships that could calibrate the preference relationship are worth acknowledging. Two adaptations to the structural equations were required because of the available data. Eq. (9b) includes the hours worked in a year in the numerator used to define the VSL. Our structural equation for the VSL (Eq. (6)) was expressed in terms of the *ex ante* MRS on an hourly basis. By contrast, the available VSL estimates are expressed in terms of annual compensation, assuming the individual considers risks and compensation per year. To establish consistency, we scaled the hourly rate on the left side of Eq. (9b) by the estimated hours worked used in (9a) and an assumption of fifty weeks worked per year. This reconciles the labor supply measure with the VSL estimate on the left side of the equation. Eq. (9c) rearranges Eq. (8) to simplify the non-linearity-scaling the Gegax et al. option price estimate for a risk change by μ — and replaces the labor supply equation (exp ($\alpha+\beta W+\mu\cdot m$)) with the level of the labor supplied in a week to be consistent with the time horizon implied by (9a).

[9] The Gegax et al. questions were developed in the context of job risks, but asked about annual gross income (without considering a labor supply adjustment). As a result, we interpret them as an option price and define it in terms of m. W in our model is a rate of pay. Their specific question is given as follows. After presenting a risk ladder and asking each respondent to select a "rung" on the ladder that comes closest to describing the risk of accidental death in their job, the WTA question asks for those below the highest risk: "consider a situation in which you were asked to face more risk on your job. What is the *smallest increase* in annual gross (i.e. before deductions and taxes) income from your job that you would have to be paid in order to accept an increase in the risk of accidental death by one step (i.e. one more death per year for every 4,000 workers)?" They are asked to circle one of thirty-seven different values ranging from \$0 to \$6,000 with an open ended "more than \$6,000."

[10] With the assistance of Shelby Gerking we were able to obtain the original survey data and computed the mean values for hours (43.94), weeks worked (47.64), and income for respondents who received the willingness to pay version of the questionnaire. The average wage rates were reported in Gegax et al. Non-wage income was approximated by multiplying the annual wage income for the survey respondents answering the WTP question (20, 521) by the sum of rental income and profit relative to total wage income in 1983 (based on the national income and product accounts, 7.15%).

To extend the logic illustrated by this simple example, one approach would be to start with a more complex indirect (or a direct) utility function and derive the implied labor supply. Or, we could change the form or add arguments to the labor supply relationship given in Eq. (3) and apply the Burtless–Hausman logic to derive a different quasi-indirect utility function. These extensions complicate the algebra but do not, in principle, preclude numerical calibration. In considering these alternatives it is important to acknowledge that each addition of a new variable as a potential observable source for preference heterogeneity adds parameters. As a result these extensions would expand the demands on the available empirical literature for choice related information.

An alternative approach for extending the logic, which we illustrate below, is more parsimonious in the number of parameters to be calibrated simultaneously. It proposes to calibrate separate indirect utility functions for different demographic groups by using choice information for each group. Not only does it reduce the set of information to be consistently structured, but it also recognizes that we may not know enough to describe how specific demographic variables influence individual preferences. This approach treats the separate models, calibrated based on each group's situation, as local approximations that are better suited to each group's choices.

The results reported in Table 1 illustrate this alternative approach with a calibration that derives a different model for different age groups. We combine estimates of the VSL derived for each of three age groups — 51–55, 56–60, and 61–65 — based on the Health and Retirement Study (HRS), reported in Smith et al. (2004) in 1991 dollars, along with the Gerking et al. WTP estimates adjusted to 1991 dollars. In this case we assume that the VSL, baseline probability, non-wage income, wage rate, and hours worked reported from the HRS are relevant for both the labor supply and VSL equations (i.e. Eqs. (3) and (6)). This assumption is especially important for m because it is possible to derive a household level estimate from the survey and use it in calibration. For the option price equation we assume the hours worked correspond to the average reported by Gerking et al. (i.e. $H=43.94$) and assume the $\widetilde{\text{WTP}}$ would apply to each of these age groups. Now the corresponding parameter estimates imply more plausible labor supply elasticities and still quite large (in absolute magnitude) non-wage income elasticities. For this group, however, a large negative response may well be more plausible than for the age group considered in Burtless and Hausman.

Table 1 – Combining contingent valuation and age specific VSL estimates

	Ages		
	51–55	56–60	61–65
VSL	\$6,051,270	\$6,421,845	\$10,038,357
p	$6.54.10^{-5}$	5.81×10^{-5}	5.85×10^{-5}
m	\$2200	\$2563	\$2830
W	\$10.27	\$10.09	\$10.24
H (hours)	37.96	37.31	35.72
Weeks/year	50	50	50
WTP	\$909	\$909	\$909
p_0	6.60×10^{-4}	6.60×10^{-4}	6.60×10^{-4}
p_1	4.10×10^{-4}	4.10×10^{-4}	4.10×10^{-4}
Calibrated parameters			
α	76.35	83.44	59.96
β	0.3137×10^{-3}	0.2905×10^{-3}	0.1779×10^{-3}
μ	-0.3305×10^{-1}	-0.3115×10^{-1}	-0.1992×10^{-1}
η	0.00322	0.00293	0.00182
ϕ	−72.72	−79.83	−56.39

One gauge of the effect of using a benefit function derived from a structural transfer versus a constant unit value would be if the new analysis alters the evaluation of important policies. Such outcomes do not imply the structural approach is the "right" one. Rather, they indicate the method for transfer matters. We don't undertake this type of comparison here for two reasons. First, and most important, one can control the outcome through the examples selected. Pre-existing studies of policy choices that imply "close calls" in terms of net benefits will yield this outcome and situations where the outcome is more decisive will not. The net result is that we are left with an examination of the factors that led the original examples to be close or not in relation to information a structural transfer brings to the analysis. We can address this issue without the examples, as we illustrate in the next section of the paper.

Second, a structural transfer may change the way the analysis is undertaken. In the case of risk — the analysis no longer relies exclusively on a point estimate for the VSL along with estimates of cases of avoided deaths due to reduced emissions (see U.S. Environmental Protection Agency, 1999 Table 5–3). Instead it would be based on the risk changes (i.e. the (p_0-p_1) in Eq. (8)) experienced by different *socio-economic* groups and the *ex ante* willingness to pay measures for them as a result. The design and structure of the information assembled in the policy analysis changes. Comparisons require consideration of more than simply the "bottom line", but should also consider the information provided by having these different details in the estimation process developed (e.g. risk changes by income and demographic group). These types of comparisons are certainly desirable but they are beyond the scope of our objectives here. Overall, then, these computations demonstrate it is possible to use multiple sources of data on labor supply, VSL estimates, and CV measures of the option price individuals would pay to reduce risks of premature death in a behaviorally consistent framework.

4. Baseline risk and age

In this section we consider the prospects for incorporating age indirectly into the behavioral model used to derive the benefit functions that are used to calibrate a preference function. This task is accomplished by altering the assumed baseline risk of death each person perceives when considering job related risks as further threats to life. The relation between age and this baseline risk then provides one way to introduce age into the analytical structure. Two alternative specifications for the role of baseline risks will be discussed and preference calibrations illustrated in each case. The first involves treating baseline and job related risks as separate lotteries that affect survival probabilities. This approach envisions a perception process where job risks scale the baseline survival probability. The second assumes that an individual considers the wage compensation/risk tradeoffs in terms of a reconstituted lottery with a different survival probability reflecting both sources of risk. This formulation assumes job risks translate the baseline risks (Evans and Smith, (in press) for further discussion). Basically, the options are to either add (translating) or multiply (scaling) the two risks — baseline risk and job related risks.

The scaling format arises with Eeckhoudt and Hammitt's (2001) reconsideration of issues originally discussed by Sussman (1984). When each process is treated as a separate lottery, the overall outcome might be described as one where each person perceives he only experiences the job risk, p, if he survives the trip to work. Thus, each worker envisions a decision framework where he considers job risk as something relevant but feels he must first "live long enough" to enter the workplace. This characterization is simply a heuristic interpretation that helps to provide intuition for the model's definition for the survival probability. There is no time dimension in such a model. The model describes how an individual would think about choices that involve a risk of death and are also influenced by another process that also affects survival. In the second lottery q is the baseline probability of death. Expected utility for this problem is given in Eq. (10) with $(1-q)(1-p)$ the probability of survival and $(1-(1-q)(1-p))$ the probability of death given the two risks.

$$\mathrm{EU} = (1-q)(1-p)\left[\frac{-\exp(-\mu m)}{\mu}+\frac{\exp(\alpha+\beta W)}{\beta}\right] + (1-(1-q)(1-p))\left[\frac{-\exp(-\mu m)}{\mu}\right] \tag{10}$$

In this case, the total differential used to define the *ex ante* MRS (or VSL) is not affected by the level of baseline risk. It contributes to both EU_p and EU_W in the same way and thus cancels from the expression for the tradeoff. As a result we have Eq. (6) for the VSL. The total differential is given in Eq. (11).

$$\mathrm{dEU} = (1-q)\left[\frac{-\exp(\alpha+\beta W)}{\beta}+\frac{\exp(-\mu m)}{\mu}-\frac{\exp(-\mu m)}{\mu}\right]\mathrm{d}p + (1-p)(1-q)\left(\beta\frac{\exp(\alpha+\beta W)}{\beta}\right)\mathrm{d}W = 0$$

As Evans and Smith (in press) demonstrate, this does not mean we can assume $\frac{\mathrm{d}W}{\mathrm{d}p}$ will be independent of factors that influence q. This result follows because compensated changes in $\frac{\mathrm{d}W}{\mathrm{d}p}$ with q must assume that W is a function of p and q.

Baseline risks also influence the option price, $\mathrm{W\tilde{T}P}$. This relationship is given in Eq. (12)

$$\mathrm{W\tilde{T}P}^* = \frac{1}{\mu}\ln\left[1+\frac{\mu}{\beta}\exp(\alpha+\beta W)+\mu m(1-q)(p_0-p_1)\right] \tag{12}$$

Age can be introduced into the analysis by assuming that q is a function of age. Thus the model composed of Eqs. (3), (6), and (12) accounts for age through the specification of q (in the expression for $\mathrm{W\tilde{T}P}$) and allows calibration of all three preference parameters. Panel A in Table 2 re-calibrates preferences using the data in Table 1 with age specific background survival probabilities taken from the Center for Disease Controls' (CDC) national vital statistics. The resulting calibrated parameters are comparable to those in Table 1, suggesting that there would be a relatively small effect on the VSL estimates if we believe age affects how people perceive their survival prospects, and adopt the scaling model with this preference specification.

Table 2 – Incorporating age specific baseline risks into preference calibration: scaling versus translating

	Ages		
	51–55	56–60	61–65
q	5.87×10^{-3}	1.33×10^{-2}	3.25×10^{-2}
VSL	$6,051,270	$6,421,845	$10,038,357
p	6.54×10^{-5}	5.81×10^{-5}	5.85×10^{-5}
m	$2200	$2563	$2830
W	$10.27	$10.09	$10.24
H (hours)	37.96	37.31	35.72
Weeks/year	50	50	50
WTP	$909	$909	$909
p_0	6.6×10^{-4}	6.6×10^{-4}	6.6×10^{-4}
p_1	4.1×10^{-4}	4.1×10^{-4}	4.1×10^{-4}
Scaling (A)			
α	76.78	84.52	61.86
β	0.3137×10^{-3}	0.2905×10^{-3}	0.1779×10^{-3}
μ	-0.3325×10^{-1}	-0.3156×10^{-1}	-0.2059×10^{-1}
η	0.00322	0.00293	0.00182
Translating (B)			
α	76.78	84.52	61.86
β	0.3155×10^{-3}	0.2944×10^{-3}	0.1839×10^{-3}
μ	-0.3325×10^{-1}	-0.3156×10^{-1}	-0.2059×10^{-1}
η	0.00324	0.00297	0.00188

Turning now to the second model where baseline risks are perceived as leading to a "reformulated lottery" with added sources of fatality risk raising the "total" odds of a fatality, the analytical expression for the VSL is modified but not the equation for *ex ante* WTP. The revised *ex ante* MRS is given in Eq. (13).

$$\frac{\mathrm{d}W}{\mathrm{d}p} = \mathrm{VSL} = \frac{1}{(1-q-p)\beta} \tag{13}$$

Using this equation together with (3), (9a), (9b) and (9c)to calibrate preference parameters, we have the results given in Panel B of Table 2. As in the case of scaling, the calibrated parameter estimates derived using the translating formulation are largely unchanged from the original calibrated values in Table 1. This relative constancy suggests that we should not be surprised by some recent empirical evidence that finds the risk tradeoffs do not change as dramatically as has been conjectured in discussions of the magnitude of the "senior discount".[11] Two quite different (but static) perspectives on the effects of age (through baseline risk) on *ex ante* marginal rates of substitution do not lead to greatly different calibration results over the range of estimates taken from the literature.

5. Calibration and estimation

There are at least four advantages to a more structural approach to benefits transfer. First, it assures consistency of the benefit estimates derived from benefit transfer with a well-defined preference function. A key implication of this consistency is the

[11] Several studies on both CV (Alberini et al., 2002; Krupnick et al., 2002) and hedonic wage (Smith et al., 2004) have found that VSL estimates do not consistently decline with age as conjectured in policy decisions.

assurance that willingness to pay can never exceed income. Second, the calibrated model can be used to derive observable "predictions," not only for WTP, but for other behavioral and economic measures as well. These predictions can in turn be used to gauge indirectly the plausibility of the benefit function. Our comparison with labor supply elasticities illustrates how this might proceed. Third, there are often multiple benefit measures available for the resource, risk, or policy outcome of interest. They can arise from models describing different types of choices. Our approach offers a basis for evaluating their mutual consistency. By virtue of developing a single model that can explain each tradeoff, one is forced to reconcile the different estimates. Finally, the choice of the preference specifications and the assumed constraints explicitly define how the baseline conditions relevant to an individual's choice such as income or demographic features, must be taken into account.

This description of advantages is hardly surprising. It is simply a re-statement of the logical process that must be developed as part of the estimation of any structural model. In this case we are simply altering the way revealed preference is used to interpret the available data. Usually an analyst does not know an individual's marginal willingness to pay for a small change in a non-market good. Instead, the analyst must derive the benefit measure from an estimated model that captures how the observed behavior and the implied tradeoffs are related to a structural model for choice. In most conventional economic analyses, this structural model is some form of constrained utility maximization.

One objection to the calibration strategy for benefits transfer may arise from concerns about making such strong a priori assumptions regarding underlying structural model. However it is important to acknowledge that such assumptions are not necessarily unusual in policy analyses. Calibration has been used in a number of different areas in economics. Initially its use in parameterizing computable general equilibrium models was controversial (see Dawkins et al., 2001). In stochastic general equilibrium models (e.g., Kydland and Prescott, 1982), the calibration approach has been called "theory with numbers". Dawkins et al. (2001) describe the primary rationale for calibration in general terms, noting that:

> The driving forces behind the use of calibration in economics is the belief that any counterfactual analysis is impossible without coherent theoretical framework and that models which are consistent with economic theory are the place to start (p.3656).

What is at issue in our proposed application of calibration is closer to Hansen and Heckman's (1996) discussion. A simple statistical summary of available results, expressed as some type of benefit measure, fails to impose a unifying structure that is essential to the ultimate use of that summary (e.g., WTP measure). In our case, we seek to assure that the extrapolation or transfer is consistent with the process assumed to generate the estimates used in the statistical model. There is nothing in the use of simple average unit values or in the predictions from a meta-regression analyses that necessarily assures the results will be consistent with underlying theory. Indeed there may well be good reasons to expect they would not be. For example, even meta-regression analyses that include all conceptually relevant factors as explanatory variables, typically do so in an ad-hoc manner. They generally use models that are linear in parameters and include variables that describe the resources, sample populations, and methods used in the primary studies in a simple specification. While these models may provide reasonable reduced form approximations of the value generating process, they do not impose the same level of theoretical consistency as a structural model would.

Benefits transfer evaluates policies as counterfactuals. They are only predictions after a decision is made to adopt the policy. Prior to that decision, they are analyses of hypothetical outcomes that can never be "checked." As a consequence, consistency requirements are especially important. We will never be able to evaluate the "predictions" that helped to suggest some policies are misguided. Even if a benefits' transfer framework meets acceptable "accuracy" standards in "predicting" measurable gains from a policy once taken, these types of results do not necessarily mean the method was as accurate for the policy that was not selected. One approach to assure the credibility of assessments that cannot be "checked" ex post is to select a method such as structural transfer that uses the properties of models for individuals' choices to integrate benefit measures from existing studies consistently.

Other objections to the calibration strategy stem from arguments that it does not necessarily make adequate use of all the available benefit information. The process we have described as structural benefit transfer treats benefit measures from the literature as the "data," defines the benefit function implied by the structural model, and then recovers the underlying preference function. For the purpose of illustration, in the examples described above, we specified a preference structure with relatively few parameters. This simplified structure allowed us to calibrate values for the preference parameters using relatively few benefit estimates. However, as these examples also show, the calibrated values can be quite sensitive to the benefit measures and baseline conditions used. Some of the variation in parameter values may be attributable to observable differences in the populations or baseline conditions studied (e.g. age differences).

If there is sufficient information from existing studies, an alternative strategy to calibration is statistical estimation of parameters. One such strategy might be labeled a structural meta analysis.[12] Our description of the general logic also implies other alternative approaches. For example, data for two types of functions derived from a structural model of choice — one for behavior and a second for a different benefit measure (e.g. a marginal willingness to pay or incremental option price) associated with changes in non-market goods (e.g., risk) — could be used together to estimate the preference parameters of a model. We usually associate this situation with joint RP/SP strategies where two types of data are collected from the same individuals, but this need not be the case for the logic to be relevant. We could envision two separate sets of individuals — a sample describing a set of individuals' behavior and another sample, perhaps of the results of benefit studies summarizing estimates of the incremental value people place on risk reductions. If we are prepared to assume both represent different "windows" on a

[12] This is the logic used in Smith and Pattanayak (2002).

common structural model of choice, it is possible to employ a composite estimation strategy. The primary limitations to implementing this suggestion appear to be consistent and complete data sets and a reluctance to impose the rather strong prior assumptions that are required for a composite structural model.

6. Implications

Economic benefits for changes in non-market goods are descriptions of the monetary tradeoffs implied by individual choice. They are not measures that people themselves use in making their decisions. The only concrete evidence on the importance of a non-market good or service to someone arises from that individual's choices. Thus, all benefit measures embody some maintained assumptions that organize choices so that they are consistent with an economic model of behavior. Preference calibration accepts this logic and specifies an algebraic relationship for preferences to help organize available benefit measures. As a result, it is explicit in the documentation of maintained assumptions. Other strategies for benefit transfer also require assumptions if their results are to be regarded as consistent measures of the benefits in new situations. In these cases, however, these requirements are often implicit. A constant unit value is taken from a past study and applied to a new policy situation. If the transfer does not explicitly highlight comparisons of the incomes of the two affected populations, differences in the resources involved, and other factors that might influence benefits for changes in the resource associated with the new situation, the "consumer" of the policy analysis has no direct way of determining that the transfer implicitly assumes these distinctions don't matter. By making them explicit — each transfer requires that these "details" must be assembled and used in constructing a benefit measures for transfer. Our example of different perspectives on the effects of age for VSL illustrates that in some cases some of the details may not matter. In others they will. If the conclusions derived from this process are very sensitive to the specification of preference functions, then transfers may need to be limited to situations where analysts can be reasonably confident that the properties implied by an assumed preference function are defensible for the policy application.

Our application of preference calibration to the valuation of risk reductions suggests a second implication. Policy concerns about the mismatch between the people whose choices yield estimates of the incremental value for risk reductions and the people experiencing the changes may not be warranted. Rather than questioning the evidence from both contingent valuation (Krupnick et al., 2002; Alberini et al., 2002) and hedonic estimates (Smith et al., 2004) suggesting that incremental values do not decline with age, our calibration results indicate that we should not have expected differences for this combination of risk level, labor supply, wages, and non-wage income. Thus, simple adjustments for age relying on value per discounted life year remaining seem questionable. The consistency requirements of preference calibration for models where age is treated as reducing the baseline survival probability confirm the CV and hedonic results. That is, large differences in the incremental values were judged as unlikely. Thus, perhaps we should "turn the tables" and question the ad-hoc adjustment of VSL per discounted life year as a credible basis for benefits transfers.

As we suggested in the previous section, the next step in benefit transfer research is estimation. In this context we would argue that benefit transfer should become a revised process for policy analysis. One might envision benefit measures being archived in a database containing the features of the resource changes that were studied and a summary of the people composing each sample. Transfer would then require evaluating the ability of the existing information to address a new policy application. Answers suggesting that the record was incomplete would not necessarily imply a completely new, large scale, data collection effort. Rather, the joint estimation strategy suggested earlier would seem to imply that smaller scale, "tailored" data collection efforts might be possible. That is, the existing research results could be treated as providing some information about a portion of the preference space. A new policy analysis might require information about a different portion of that preference space. Designing a strategy that explores the new dimensions, and partially overlaps what we know, allows linking the existing results with the new information. Estimators that incorporate the restrictions implied by a structural model of choice permit systematic "learning" from the research record. That is, the model together with the multiple samples of information derived from people's choices offer the opportunity to exploit both the existing record of findings from past research and the new data collected in ways that were designed to be responsive to policy needs.

This revised process is not a "pie-in-the-sky" proposal. The estimation methods exist and are being used in other subfields of economics (see Imbens and Lancaster, 1994). What is not known is whether this over-arching view of learning is a reasonable one. It relies on the plausibility of the conventional constrained utility maximization model with a careful specification of the objects of choice. These details must be structured by analysts for environmental resources and risks that people may not understand in the exact ways economic models represent them. As many authors have acknowledged, all models must make assumptions about how to translate the attributes of a choice situation into a formal description that allows the implied tradeoffs to be characterized. Inevitably this introduces a set of maintained assumptions. In the case of structural benefit transfers we don't know if the prior information creating the structural links between existing results and new, tailored data sets is reliable enough to enhance the transfer process.

Of course, a multiple sample approach, potentially relying on a generalized method of moments or an alternative, classical estimation methodology, is not the only potential strategy for developing statistical models using past benefit measures and new sources of data. Both Moeltner et al. (2005) and Bergland (2005) have proposed hierarchical Bayesian methods, calling for the use of multiple priors. In Bergland's case, one prior is used for parameters influencing the distribution of the benefit measure in a given context and a second prior captures the distribution of these parameters over different contexts. Moeltner et al. consider a specific situation where there is incomplete information about some of the proposed determinants of a meta function summarizing available benefit measures. While these authors focus on the methods used in the primary benefit studies, the general point could apply to a wide range of possibilities related to meta-regressions for transfer because the available literature rarely spans the full range of study and resource attributes hypothesized to influence benefit measures. As a result, analysts can often "code" studies in a variety of ways, sometimes highlighting the features of the resources considered and other times the methods used, but not both.

The Bayesian approach relies on the ability to specify formal priors regarding the influence of methods factors and resource characteristics (Moeltner et al. example) or other contextual determinants (Bergland's example) on benefits estimation. One advantage of the Bayesian approach is that it also provides a more systematic way to *aggregate* the heterogeneous preferences that underlie summary benefit measures that are then transferred for a policy application. In contrast, structural benefit transfer methods (as we have explained in this paper) treat these issues in a simpler, less formal way — by calibrating separate preference functions (and their associated benefit functions) for different sets of individuals, identified for example by their observable characteristics such as age.

At present, research on both strategies for benefit transfer is just beginning so a recommendation for one of the alternative strategies cannot be offered. We do know, given the increased scale of benefit-cost analyses for policy-making, that research evaluating these alternative strategies would seem to be overdue.

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